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Fertilizer Source and Soil Aeration Effects on Runoff Volume and Quality

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ABSTRACT

Minimizing runoff losses from grasslands may benefit the producer and abate potential eutrophication of aquatic systems. This study was conducted to evaluate the effects of fertilizer source and soil aeration on the volume and quality of runoff from grassed plots. Sixteen tall fescue [*Festuca arundinacea* Schreb.]–bermudagrass [*Cynodon dactylon* L.] plots were established on Altavista sandy-loam soil (fine-loamy, mixed, semiactive, thermic Aquic Hapludults) in Georgia, USA. Two fertilizer sources (inorganic fertilizer [IF] and broiler litter [BL]) and two aeration treatments (aerated and nonaerated) were factorially combined to generate four experimental treatments. Broiler litter was applied at 1765 kg dry matter ha^{-1} and IF was applied to match nutrient rates applied with BL (36 kg available N ha^{-1}, 39 kg P ha^{-1}, 60 kg K ha^{-1}). Simulated rainfall was applied immediately after fertilizer application and 1 mo later. Runoff samples were analyzed for dissolved reactive phosphorus (DRP), total Kjeldahl phosphorus (TKP), and ammonium (NH_4–N). In the first runoff event, plots fertilized with IF lost more TKP than plots fertilized with BL (3.4 vs. 1.1 kg P ha^{-1}). In contrast, plots fertilized with BL lost more NH_4–N than plots fertilized with IF (1.4 vs. 0.6 kg N ha^{-1}). These results support the use of different weighting factors for BL and IF when assessing their potential for contaminating surface runoff. Aeration numerically reduced runoff volume by 27%, though not significantly, in the first runoff event ($P = 0.16$), but did not affect runoff volume 1 mo later. Aeration did not affect the mass losses of DRP, TKN, and NH_4–N. These results indicate that aeration of hayed grasslands on these soils would not be expected to significantly affect the volume and quality of surface runoff.

In the past decade, there has been considerable concern about nutrient losses from agricultural systems and the consequences of those losses on the health and sustainability of aquatic ecosystems (Sharpley et al., 1994; Carpenter et al., 1998). In the southeastern USA, scientists have been predominantly concerned with P losses in overland flow (i.e., runoff) when animal manures are land applied to grasslands (i.e., pastures and haylands). This concern arises from the fact that P is usually the limiting nutrient for aquatic production in streams and lakes (Schindler, 1977). Although N is usually not considered a nutrient of concern in streams and inland lakes, N should also be taken into account because N transported in streams and rivers can be the primary limiting nutrient for aquatic production in coastal areas (Carpenter et al., 1998).

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Recent work in the Southern Piedmont of Georgia, USA, has shown annual losses of 5.1 to 9.7 kg DRP ha^{-1} and 1.5 to 13.5 kg NH_4–N ha^{-1} from grasslands receiving BL to supply the annual N requirements of tall fescue–bermudagrass mixtures (Pierson et al., 2001). Annual background losses from these grasslands before BL amendment was applied were estimated as 0.6 kg DRP ha^{-1} and 0.8 kg NH_4–N ha^{-1} (Kuykendall et al., 1999). Therefore, reducing contamination of surface waters with N and P would be an important goal for managers of grasslands fertilized with BL. Nitrogen and P losses in surface runoff depend on the volume of runoff and concentrations present in runoff; thus, losses could be reduced by reducing runoff volume or the concentrations of N and/or P in runoff (Pierson et al., 2001). One potential means of reducing runoff losses is soil aeration. Soil aeration is a mechanical treatment that may achieve these objectives without causing major destruction of surface vegetation in grasslands (Taylor et al., 1983; Burgess et al., 2000). Aerating machines make slits or holes that are 7 to 20 cm deep, 3 to 15 cm long, and 1 to 3 cm wide. Aeration may also partially incorporate manure or IF applied into the soil, increase contact time between water, fertilizer, and soil to facilitate P adsorption by the soil, and increase surface roughness, which may increase water retention and reduce runoff.

Most studies of pasture aeration have concentrated on forage production with mixed results. Aeration has been found to increase (Davies et al., 1989), decrease (Gordon et al., 2000), or have no effect (Taylor et al., 1983; Mahli et al., 2000; Burgess et al., 2000) on forage production. However, few studies have evaluated the effects of aeration on surface runoff. van Vliet et al. (2000) studied the effect of aeration on runoff quantity and quality from orchard grass [*Dactylis glomerata* (L.)] plots fertilized with liquid dairy manure in Canada and found that aeration reduced runoff volume and nitrate-N loading in runoff by approximately 50%, while reducing ammonia-N and total N loading by over 70%. Considering the limited information available on the potential environmental impact of aeration, the objective of this study was to evaluate the effects of fertilizer source and soil aeration on runoff volume and quality produced during rainfall simulations in hayed grass plots fertilized with BL or IF. Study hypotheses are: (i) that runoff losses of N and P will be greater with IF than with BL because nutrients in IF are more water soluble than those present

Abbreviations: AN, ammonium nitrate; BL, broiler litter; DRP, dissolved reactive phosphorus; IF, inorganic fertilizer; TKP, total Kjeldahl phosphorus.

in BL and (ii) that aeration will increase water infiltration, thereby decreasing runoff volume and runoff losses of N and P.

MATERIALS AND METHODS

Field Study

This study was conducted at the University of Georgia, Central Research and Education Center near Eatonton, GA (33°24′ N; 83°29′ W; elevation = 150 m) in Spring 2002. Sixteen 0.75 by 2 m plots were established on south-facing, 2 to 6% hillslopes of Altavista sandy-loam soil. The plots were established on a bermudagrass pasture that had been overseeded with tall fescue in Fall 1998, so a mixture of both grasses was present at the time of the study. To isolate the surface hydrology of each plot, 35-cm galvanized steel borders were inserted 20 cm into the soil and a runoff collection system was installed at the downslope end of each plot. Before each rainfall simulation, three soil samples (1.75-cm ID) were collected within each plot from the 0- to 2-, 0- to 5-, and 0- to 15-cm depths, composited, and analyzed for Mehlich I soil-test P (Mehlich, 1953).

Two fertilizer sources (i.e., IF and BL) were factorially combined with two soil mechanical treatments, either aerated or nonaerated, to generate four experimental treatments that were arranged in a randomized complete block design with four replications. Because of the topography of the available space, each of the blocks was placed in a different landscape position (i.e., shoulder, backslope, footslope, and toeslope). A soil core (3 cm ID, 120 cm long) was taken with a hydraulic probe from each block for particle-size analysis and determination of P adsorption isotherms.

The BL used was obtained from a broiler (*Gallus gallus domesticus*) house that had pine wood shavings as bedding material and had housed four flocks of birds before "clean out." Total N and total P in BL were determined by Kjeldahl digestion (Baker and Thompson, 1992). Inorganic N was determined by shaking 20-g litter samples with 200 mL of 1*M* KCl for 30 min and measuring inorganic N in the extract by colorimetric procedures (Crooke and Simpson, 1971; Keeney and Nelson, 1982). Water-soluble P in litter was measured by shaking 20-g samples with 4 L of deionized water for 4 h (Pierson et al., 2001) and determining DRP in the extracts bythe Murphy and Riley (1962) technique. Potassium was determined by ashing the samples at 500°C, dissolving residue in nitric acid, and measuring K with an inductively coupled Plasma Spectrophotometer (Soltanpour et al., 1996). Litter water content was determined by drying at 65°C for 48 h. At the time of application, the litter had 0.31 kg H_2O (kg dry litter)$^{-1}$, 41.3 g total N kg^{-1}, 22.3 g total P kg^{-1}, 34.0 g K kg^{-1}, 6660 mg NH_4–N kg^{-1}, and 1850 mg water-soluble P kg^{-1}.

Litter was applied at 1765 kg dry matter ha^{-1} to supply 36 kg available N ha$^{-1,}$ assuming 50% of the N would be available, 39 kg total P ha^{-1}, and 60 kg K ha^{-1}. The IF sources used were ammonium nitrate (AN), triple superphosphate (TSP), and potassium chloride applied at the same rates of available nutrients as supplied by the BL (36 kg N ha^{-1}, 39 kg P ha^{-1}, 60 kg K ha^{-1}).

In March 2002, two rainfall simulators (Tlaloc 3000, Joern's Inc., West Lafayette, IN) were used to apply simulated rain to the plots to determine variability among plots before application of treatments. In all simulations, a rain of 50 mm h^{-1} was applied until initiation of runoff and was continued for an additional 30 min. Time to initiation of runoff was recorded. In-toto and 5-min incremental samples were taken during runoff. Each rainfall simulator rained on two plots at the same time. The grass on the plots was cut to a height of 10 cm and removed before each rainfall simulation.

On 22 Apr. 2002, fertilizer and initial aeration treatments were applied and a rainfall simulation was conducted. Plots were aerated with a custom-made machine consisting of three "wheels" spaced 25 cm apart and mounted on a single axle attached to a frame. Each wheel contained 10 spikes that were equally spaced around the circumference of the wheel. The spikes were 9 cm long and when totally inserted into the soil produced a wedge-shaped hole that was 6 cm long and 2 cm wide at the top and 2 cm long and 1 cm wide at the bottom. The distance between holes within the row of holes generated by each wheel was approximately 15 cm. This machine was designed to simulate the work of commercially available, field-scale machines, such as the ones manufactured by AerWay (Holland Hitch Texas, Wylie, TX). Aeration of each plot was performed by lifting the machine over the plot border, placing a 200-kg weight on it to facilitate soil penetration, and rolling it downslope along the length of the plot. Two passes were made in each plot, which generated six rows of holes along the direction of the slope.

On 22 May 2002, assigned plots were aerated a second time to enhance any possible aeration effect and a second post-aeration rainfall simulation was conducted. The research area received 54 mm of natural rainfall in April and 72 mm in May, but natural rainfall did not fall directly on the plots because the plots were covered with a tarp during rainfall events.

Runoff samples were filtered through 0.45-μm cellulose-nitrate membranes, placed on ice in dark coolers, and transported to an analytical laboratory for analysis. Samples were analyzed for NH_4–N by the salicylate-hypochlorite method (Crooke and Simpson, 1971) and for DRP by the molybdate-blue method (Murphy and Riley, 1962). Total Kjeldahl P was determined on unfiltered runoff samples by Kjeldahl digestion according to United States Environmental Protection Agency (USEPA) method 351.2 (USEPA, 1979). The samples collected every 5 min represented point estimates of concentrations, rater than flow-weighted concentrations; thus, loads could not be estimated by simply multiplying concentrations by the runoff volume accumulated every 5 min. Instead, the point estimates of concentrations were plotted as a function of cumulative runoff and cumulative losses were calculated by integrating the area under the plot using Simpson's rule in Mathcad 2001 (Mathsoft Inc., Cambridge, MA.).

An analysis of variance (SAS Institute Inc., 1994) was performed to evaluate the main effects of block (i.e., landscape position), fertilizer source, aeration treatment, and the interaction between fertilizer source and aeration treatment. Fisher's least significant difference (LSD) was used to separate means. Differences were considered to be significant at $P < 0.05$.

Soil samples (0–15 cm) taken from each block were used for particle-size analysis and P adsorption isotherms. Particle-size analysis was conducted using the hydrometer method (Gee and Dani, 2002) and P sorption isotherms were determined as described by Graetz and Nair (2000). Linear regression was used to fit the data from the adsorption isotherms to the Langmuir equation:

$$C_L/S = 1/(kS_{max}) + C_L/(S_{max})$$

where C_L is the concentration in solution (mg P L^{-1}) after 24-h equilibration, S (mg P kg^{-1}) is the total amount of P retained, S_{max} (mg P kg^{-1}) is the P sorption maximum, and k (L mg P^{-1}) is a parameter related to the bonding energy.

Laboratory Study

A laboratory study was conducted in triplicate to evaluate the leachability of NH_4–N in BL and AN. Broiler litter (1.25 g)

Table 1. Runoff volume collected in 30 min of simulated rain from plots fertilized with broiler litter or inorganic fertilizer, with or without aeration treatment (22 Apr. and 22 May 2002).

Mechanical treatment	Broiler litter	Inorganic fertilizer	Mean	*P*-value†
	Runoff volume, L m^{-2}			
		22 Apr. 2002		
Nonaerated	19.6 (13.3)‡	19.8 (4.2)	19.7	0.16
Aerated	13.4 (5.5)	15.4 (6.7)	14.4	
Mean	16.5	17.6		
P-value†	0.76			
		22 May 2002		
Nonaerated	16.1 (6.2)	18.3 (5.9)	17.2	0.98
Aerated	14.1 (1.5)	20.2 (6.0)	17.2	
Mean	15.1	19.3		
P-value†	0.14			

† Probability of Type I Error for comparison of means.
‡ Value in parenthesis is standard deviation.

or AN (0.05 g; 3 granules) containing 8500 ug NH_4–N was placed inside a Buchner funnel (6.5 cm ID) that had a Whatman #1 paper at the bottom. Thirteen millimeters of simulated rain was subsequently applied in 16 min to simulate the rain received by the field plots before initiation of runoff. The simulated rain was generated with a device consisting of a peristaltic pump (model: IPC-–24, Isamatec, Switzerland) connected to plastic tubing that delivered water to a manifold with 21 hypodermic needles (22 gauge × 37.5 mm long) arranged in a circle (4.45-cm ID). The needles generated 10.4-mg droplets, and the manifold delivered a total flow rate of about 1.3 mL min^{-1} directly over the Buchner funnel. Water percolating through the BL or AN on the funnel was collected in a 250-mL Erlenmeyer flask and analyzed for NH_4–N by the salicylate-hypochlorite method (Crooke and Simpson, 1971). An analysis of variance was conducted to compare the percentage of NH_4–N leached from BL and AN.

RESULTS AND DISCUSSION

Analysis of the runoff data collected before treatments were applied showed that there were some differences in runoff volume among blocks (i.e., landscape positions; $P < 0.05$), but not between plots within a block. The footslope position had less runoff than the other positions. Thus, blocking by slope position was used to better assess the effects of fertilizer source and aeration treatments. After treatments were applied, analysis of data showed no interaction between fertilizer source and mechanical treatment ($P > 0.05$). Therefore, results of main treatment effects (fertilizer source and mechanical treatment) are discussed separately.

Effect of Fertilizer Source

Fertilizer source did not affect runoff volume in either of the rainfall simulation events (Table 1). Runoff from BL (15.1 L m^{-2}) tended to be lower, though not significantly, than that from IF (19.3 L m^{-2}) in May ($P = 0.14$). This result may have been caused by increased microbial activity that can occur after adding BL to soil (Cabrera et al., 1994). Fertilization with BL added approximately 900 kg C ha^{-1}, of which about 40% is rapidly decomposable to CO_2 (Gale and Gilmour, 1986). The addition of a labile C source could lead to an increase in microbial activity, which in turn could increase soil macroaggregation, improve infiltration, and reduce runoff. In a study with a degraded soil, Watts et al. (2001) found that the addition of grass residues led to an increase in macroaggregation within 2 to 8 wk after residue addition. In the same study, about 40% of the residue C was released as CO_2 in 8 wk of incubation, which is similar to the typical decomposition pattern of BL (Watts et al., 2001).

Plots fertilized with IF lost a larger mass of DRP and TKP ($P < 0.05$) than plots fertilized with BL in both simulated rainfall events (Tables 2 and 3, Fig. 1 and 2). These results were partly expected because P in TSP is more than 95% water soluble, whereas P in the BL used was only 8% water soluble. These results are in contrast, however, to those of Nichols et al. (1994), in which plots fertilized with BL or inorganic fertilizer at 87 kg P ha^{-1} showed no significant difference in the mass of P loss. Nichols et al. (1994) found that plots with IF had significantly higher concentrations of DRP in runoff than in BL, but high variability in runoff volume prevented detection of significant differences in the mass of DRP lost in runoff.

Southeastern USA soils are inherently low in P and P supplementation is commonly necessary to maximize forage and crop production; thus, from a fertilizer efficiency point of view, fertilizers that lead to smaller runoff losses would be favored. Because IF treatments lost more P in runoff than BL treatments, decisions based

Table 2. Cumulative dissolved reactive P (DRP) loss in 30 min of simulated rain from plots fertilized with broiler litter or inorganic fertilizer, with or without aeration treatment (22 Apr. and 22 May 2002).

Mechanical treatment	Broiler litter	Inorganic fertilizer	Mean	*P*-value†
	DRP loss, kg P ha^{-1}			
		22 Apr. 2002		
Nonaerated	0.91 (0.61)‡	3.22 (1.41)	2.06	0.37
Aerated	0.79 (0.29)	2.58 (1.07)	1.69	
Mean	0.85	2.90		
P-value†	0.0007			
		22 May 2002		
Nonaerated	0.24 (0.09)	0.42 (0.21)	0.33	0.99
Aerated	0.23 (0.03)	0.43 (0.12)	0.33	
Mean	0.23	0.42		
P-value	0.0164			

† Probability of Type I Error for comparison of means.
‡ Value in parenthesis is standard deviation.

Table 3. Cumulative total P loss in 30 min of simulated rain from plots fertilized with broiler litter or inorganic fertilizer, with or without aeration treatment (22 Apr. and 22 May 2002).

Mechanical treatment	Broiler litter	Inorganic fertilizer	Mean	*P*-value†
	P loss, kg P ha^{-1}			
		22 Apr. 2002		
Nonaerated	1.16 (0.87)‡	3.86 (1.35)	2.51	0.28
Aerated	1.05 (0.38)	3.02 (1.31)	2.03	
Mean	1.10	3.44		
P-value †	0.0003			
		22 May 2002		
Nonaerated	0.32 (0.11)	0.54 (0.28)	0.43	0.78
Aerated	0.35 (0.03)	0.57 (0.16)	0.46	
Mean	0.33	0.55		
P-value †	0.0319			

† Probability of Type I Error for comparison of means.
‡ Value in parenthesis is standard deviation.

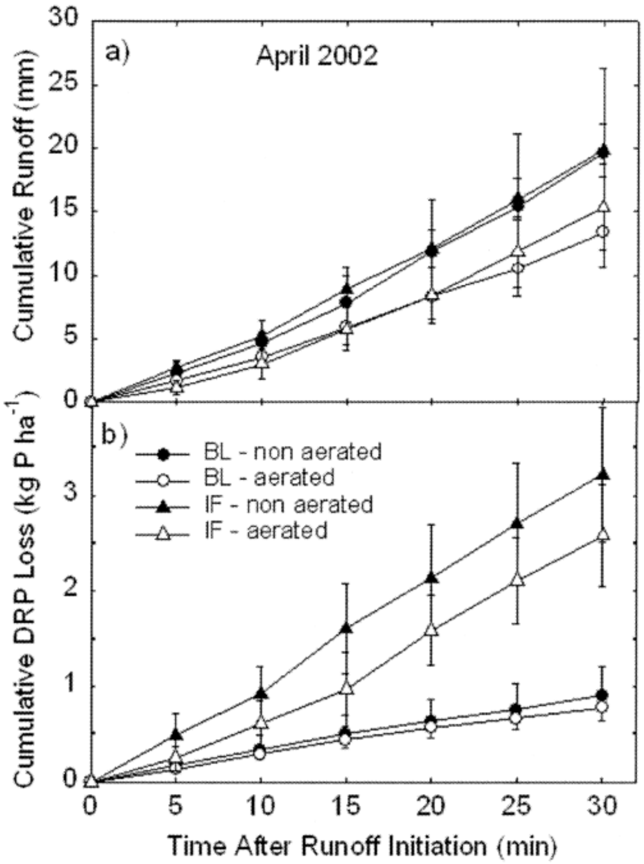

Fig. 1. (a) Cumulative runoff volume and (b) cumulative dissolved reactive P (DRP) loss during 30 min of runoff from 1.5-m² plots fertilized with broiler litter (BL) or inorganic fertilizer (IF), with or without soil aeration in April 2002. Vertical bars are standard errors.

on fertilizer efficiency would favor BL use in grasslands when used at recommended P rates that would not lead to buildup of soil-test P. In addition, from a water quality point of view, BL would be favored over IF, when applied at the same P rate, because smaller runoff losses would lead to fewer impacts on aquatic systems. It should be pointed out however, that BL has not been traditionally used at rates that supply only the P requirements of grasslands. Instead, BL has been typically applied to supply the N requirements of grasslands, which have led to a buildup of soil P (Kingery et al., 1993) as well as to large runoff-P losses (Pierson et al., 2001).

Table 4. Cumulative ammonium N (NH_4–N) loss in 30 min of simulated rain from plots fertilized with broiler litter or inorganic fertilizer, with or without aeration treatment (22 Apr. and 22 May 2002).

Mechanical treatment	Broiler litter	Inorganic fertilizer	Mean	*P*-value†
	NH_4–N loss, kg N ha^{-1}			
		22 Apr. 2002		
Non Aerated	1.54 (1.01)‡	0.60 (0.44)	1.07	0.68
Aerated	1.31 (0.49)	0.57 (0.27)	0.94	
Mean	1.42	0.59		
P-value†	0.02			
		22 May 2002		
Non Aerated	0.02 (0.02)	0.03 (0.04)	0.02	0.39
Aerated	0.02 (0.02)	0.05 (0.03)	0.03	
Mean	0.02	0.04		
P-value†	0.09			

† Probability of Type I Error for comparison of means.
‡ Value in parenthesis is standard deviation.

Over the last 5 yr, most states in the USA have been involved in the development of a tool to assess the risk of P loss from agricultural fields and grasslands. This tool, commonly known as the Phosphorus Index (Lemunyon and Gilbert, 1993), considers P sources, P transport, and best management practices when assessing the potential for P loss. A controversial issue is whether P sources should be weighted differently in terms of their ability to contribute P to runoff. The results of this study support the use of different weighting factors for BL and IF in the Phosphorus Index.

Ammonium losses varied between the April and May simulated rainfall events (Table 4). In April, NH_4–N concentrations in runoff were lower ($P < 0.001$) from plots fertilized with AN than from plots fertilized with BL for each 5-min incremental sample as well as for the cumulative 30-min sample (Fig. 3). The BL treatment lost more NH_4–N than the IF treatment (Table 4)

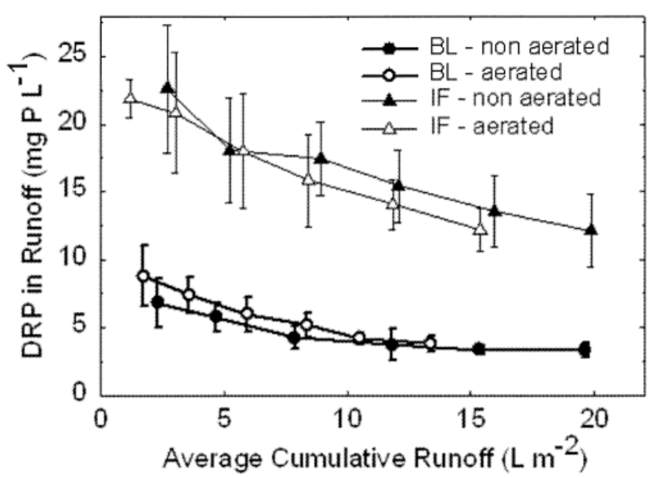

Fig. 2. Average cumulative runoff volume relative to dissolved reactive P (DRP) concentration in runoff for plots fertilized with broiler litter (BL) or inorganic fertilizer (IF), with or without soil aeration, in April 2002. Vertical bars are standard errors.

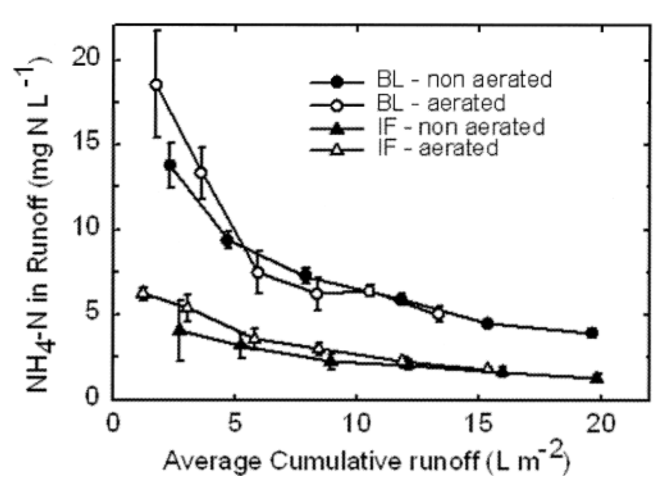

Fig. 3. Average cumulative runoff volume relative to ammonium N (NH_4–N) concentration in runoff for plots fertilized with broiler litter (BL) or inorganic fertilizer (IF), with or without soil aeration, in April 2002. Vertical bars are standard errors.

even though the amount of NH_4–N applied with BL (12 kg N ha^{-1}) was smaller than the amount applied with AN (18 kg N ha^{-1}). This result may be explained by the high hygroscopicity of AN in contrast to the hydrophobicity of BL. Ammonium nitrate has a critical relative humidity of 63% at 20°C (International Fertilizer Development Center FDC 1979), which indicates that AN dissolves when the relative humidity is above 63%. This would facilitate quick dissolution of AN at the start of the rainfall simulation, before initiation of runoff. Furthermore, AN is highly soluble in water (1.18 kg NH_4NO_3 L^{-1}; Lide, 2002), which would allow simulated rainfall to dissolve and carry a significant amount of AN into the soil at the start of the rainfall simulation. In contrast, BL is hydrophobic in nature because of the lignin present in the pine wood shavings used as bedding material (Cochaux et al., 1995). This hydrophobicity would delay the solubilization of NH_4–N in BL, especially at the start of the rainfall simulation. Therefore, less of the NH_4–N present in BL would initially be moved into the soil, leaving more NH_4–N exposed on the surface to potentially runoff later in the simulation. To test this hypothesis, a laboratory study was conducted in which a simulation of 13-mm rainfall over 16 min was used to estimate the amount of NH_4–N that could be leached from BL and IF before initiation of runoff. The results showed that the percentage of NH_4–N leached by the 13-mm simulated rainfall was 88% for IF and only 37% for BL ($P < 0.01$). These results support the proposed explanation for the larger runoff losses observed with BL than with IF.

In May, there were no significant differences in NH_4–N concentrations between BL and IF, although there was a trend ($P = 0.10$) of lower concentrations in the BL plots (data not shown). This was also true for mass losses of NH_4–N (Table 4), which were about an order of magnitude smaller than those in April (Table 4). In addition, in the May simulation, NH_4–N runoff losses decreased to 1.4% of the losses observed in April, whereas DRP runoff losses only decreased to 27% of the April losses. These results agree with those of Pierson et al. (2001) who found that NH_4–N concentrations in runoff decreased rapidly after BL application, whereas DRP concentrations remained elevated for a longer period of time. This may be explained by the differential fate of NH_4–N and P in soil. Ammonium can be volatilized as ammonia (NH_3), leached into the soil, or converted to NO_3–N. In contrast, P is adsorbed relatively quickly by soil minerals, which leaves P near the soil surface where it could be desorbed as it comes in contact with surface runoff. Results of P sorption isotherm determinations indicated a strong soil capacity to adsorb P at this site, with a mean S_{max} value of 823 mg P kg^{-1} and k value of 0.32 L mg P^{-1}. Similarly, soil-test P values before fertilizer application showed that the average value at the 0- to 2-cm depth was 2.5 times larger than the average value at the 0- to 5-cm depth (5.0 vs. 2.0 mg P kg^{-1}). The ratio between these two depths increased to 3.8 1 mo after fertilizer application (16.1 vs. 4.2 mg P kg^{-1}), indicating an accumulation of P near the soil surface.

Effects of Aeration

Aeration did not affect runoff volume, but in April there was a trend, though not significant ($P = 0.16$), toward a 27% reduction in runoff volume from aerated plots (Table 1). Also, aeration had no effect on time to initiation of runoff (15.3 and 17.0 min for aerated and non-aerated plots, respectively) or on cumulative DRP and TKP losses (Tables 2 and 3). These results are in contrast to those of van Vliet et al. (2000) who found that aerating orchard grass plots in Canada reduced runoff volume by approximately 50% and total N loss by over 70%. The lack of a significant aeration effect in our study may have been caused by differences in soil characteristics or by the orientation of aeration slits with the slope. In this study, aeration slits were made parallel to the slope unlike the van Vliet et al. (2000) study where the slits were made perpendicular to the slope. Soil aeration would be expected to increase water infiltration in relatively well-drained soils in which compaction of the surface horizon has caused an overall reduction in infiltration rate. Altavista sand loam is a moderately well-drained soil that would be expected to respond to aeration when compacted. The area in which this study was conducted was cut for hay for 10 yr previous to the study; thus, any soil compaction that occurred during those 10 yr would have been caused by the haying machinery used. It is possible that the degree of compaction caused by machinery in this soil was rather limited, which would limit the response to aeration. This observation suggests the need to evaluate aeration treatments on grazed grasslands, where compaction may be larger than in hayed grasslands (Davies et al., 1989), and to generate slits perpendicular to the slope so as to interrupt the flow of water.

CONCLUSIONS

The results of this study showed that runoff losses of TKP immediately after fertilizer application were about three times larger with IF than with BL. This suggests that P added as TSP should have a larger weight than that added with BL when assessing its potential to contaminate surface runoff. In contrast, runoff losses of NH_4–N immediately after fertilizer application were about two times larger with BL than with IF. If this loss is corrected to account for differences in the initial amounts of NH_4–N added (12 kg N ha^{-1} with BL and 18 kg N ha^{-1} with AN), then the amounts lost are more than three times larger with BL than with AN. This should also be taken into account when assessing the potential of these two sources to contaminate surface runoff. Aeration did not affect runoff volume or the mass loss of TKP, DRP, and NH_4–N. Additional research should be conducted in grazed grasslands to further assess the potential for aeration to reduce losses of N and P in runoff.

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